As CO_2 Levels Rise, Plants—and Humans—Respond

Agricultural Research Service plant physiologist Lewis Ziska has found that poison ivy is thriving—and becoming more toxic—because of increased carbon dioxide (CO_2) levels in the atmosphere. And when pollen wafts through the air, science pundits cite Ziska's work showing that global climate change is ramping up the production of ragweed allergens.

But Ziska believes global climate change creates challenges that far exceed formidable weeds. "We need to know how these atmospheric shifts will affect our ability to feed people around the world," he says.

Ziska works at the Crop Systems and Global Change Laboratory (CSGCL) in Beltsville, Maryland, and often collaborates with CSGCL plant physiologists Richard Sicher and Jim Bunce on food plant research. "Increased CO_2 for most crops is a positive," says Sicher. "You can double CO_2 and almost anything will grow. The detrimental changes can be more subtle."

PEGGY GREB (D1552-1)

Soil scientist Dennis Timlin (left) and plant physiologist Richard Sicher measure chlorophyll concentrations in corn leaves exposed to elevated carbon dioxide.

Ziska's findings on soybean growth are a case in point. In a typical production year, almost all soybeans planted in the United States are those genetically modified to resist herbicides, such as glyphosate, so farmers can eradicate weeds without harming their crops.

Ziska found that with typical precipitation levels, growth of genetically modified, glyphosate-resistant soybeans is stimulated by elevated CO_2 levels—but so is the growth of weeds that are typically kept in check by the herbicide. So producers may need new strategies for managing soybean weeds as CO_2 levels rise.

Rice May or May Not Be Nice

Ziska also worked with Anna McClung, research leader at the ARS Dale Bumpers National Rice Research Center at Stuttgart, Arkansas, to assess how strains of cultivated and wild red rice respond to elevated CO_2. A weedy relative of cultivated rice, red rice can constrain production of rice grown for food.

The scientists found that elevated CO_2 levels increased growth in both types of rice but more so in red rice. Significant differences in the rates and amount of growth were visible just 27 days after the seeds were planted. These growth differences indicate that, as CO_2 levels increase, so too might competition between wild and cultivated rice. One way of preventing this would be for breeders to identify genetic traits in wild rice that support increased growth and breed these traits into cultivated varieties.

Ziska also partnered with scientists in China and concluded that when there was enough nitrogen in the soil to support growth, cultivated rice production was enhanced by rising CO_2 levels. But when soil nitrogen levels were low, barnyardgrass—a common weed in paddy rice—was able to thrive at the expense of cultivated rice.

Wheat and Corn Findings

Ziska also conducted a 3-year field study to see whether the modern wheat line Oxen was as sensitive to rising CO_2 levels as Marquis, a wheat line widely cultivated in the first half of the 20th century. At current CO_2 levels, Oxen seed production exceeded Marquis seed production. But at the higher CO_2 levels expected in the next 50 to 100 years, the two cultivars didn't have a notable difference in seed yield. And for 2 of the 3 years, Marquis exceeded Oxen in overall vegetative biomass production. Ziska believes these findings indicate that the ability of different wheat lines to respond to CO_2 may depend on how the plants process the additional carbon.

Meanwhile, Sicher and two other CSGCL colleagues—soil scientist Dennis Timlin and research leader Vangimalla Reddy—partnered with ARS plant physiologists Dennis Gitz and Jeff Baker to study the interrelated effects of elevated CO_2 levels

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Plant physiologist James Bunce measures carbon dioxide (CO_2) uptake and water loss from leaves of soybeans grown at elevated CO_2 concentrations. Measurements on plants grown at current ambient CO_2 concentration and at elevated concentrations reveal whether there are long-term adjustments to the elevated concentrations.

and temperature on corn. Soo Hyung-Kim, who is now an assistant professor at the University of Washington, was also one of the principal investigators.

The team grew corn in sunlit-controlled environmental chambers at five different temperatures and at two concentrations of CO_2—current levels and doubled levels. Data on photosynthesis rates, leaf appearance, aboveground biomass accumulation, leaf area, and enzyme activity essential for sugar production was gathered and used to develop a model to predict corn response to elevated temperatures.

The data indicate that higher levels of CO_2 do not stimulate the growth of corn plants. But as CO_2 levels rise, so do air temperatures. Warmer conditions cause leaves to develop earlier, but above-ambient temperatures cause leaves to expand more slowly, and aboveground biomass accumulation is suppressed. So rising CO_2 concentrations won't have much direct impact on corn growth and production, but warmer temperatures due to CO_2 enrichment can adversely affect plant growth.

This kind of information could help farmers and policymakers develop more nuanced strategies for dealing with climate change.

Studies that Sicher and Bunce conducted on wheat indicate that it matures earlier when CO_2 levels are elevated. Although elevated CO_2 treatments can increase yields depending on the variety, a shorter growing season is known to reduce wheat's yield potential. Wheat yields are also expected to fall as ambient temperatures increase.

"It's a double whammy for wheat," Sicher notes.

Sicher and Bunce also found that in barley, leaf levels of amino acids decreased when CO_2 levels were elevated. Since amino acids help produce proteins key for photosynthesis, the plant's ability to grow and thrive is reduced.

What About Weeds?

Ziska has also collaborated on work showing that cheatgrass and Canada thistle flourish when CO_2 levels rise. Cheatgrass is an invasive annual that has become a major headache for rangeland managers in the western United States because it fuels wildfires and outcompetes native grasses. Canada thistle is an aggressive perennial weed that reduces forage consumption by cattle in pastures and rangeland.

Weeds in the wild have acquired a diverse genetic pool that helps them adapt to environmental challenges such as pests, disease, or extreme weather conditions. For these plants, global climate change is just another evolutionary contest.

"The greater range of responses observed for weeds in increasing atmospheric CO_2 and temperatures may be related to their greater genetic diversity relative to crops," Ziska explains. "In other words, the greater the gene pool, the more likely it is for a species to respond to a rapid environmental change."

Bunce found that different dandelion genotypes vary in fitness when CO_2 levels are elevated and that some varieties could adapt rapidly to rising CO_2 levels. "It's possible that dandelions, which are a cool-season, quick-growing, springtime perennial, could have traits we could introduce into cultivated crops that have similar profiles," he says.

"There's a tremendous response variation in plants of the same genus and species," Ziska concludes. "We need to see if we can utilize these traits to meet our future food needs."—By **Ann Perry,** ARS.

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At the ARS Crop Systems and Global Change Laboratory, Beltsville, Maryland, plant physiologists Lewis Ziska and Martha Tomecek examine the response of different rice cultivars to changes in carbon dioxide and temperature. ARS scientists at Beltsville and Stuttgart, Arkansas, are working to select rice lines best adapted to the changing climate.